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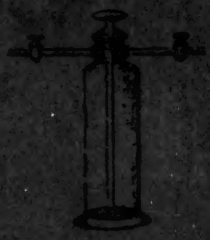

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RELATIVE ADHESIVENESS OF THE COPPER FUNGICIDES

O. Butler and T. O. Smith

The relative adhesiveness of the copper fungicides has been studied by several authors.

Girard (1) used in his experiment potted potato plants and studied the effect on relative adhesiveness of artificial rains of three different intensities, to wit in imitation of a heavy storm shower, 17 mm. of water in twenty-two minutes; a heavy rain, 15 mm. of water in six hours; and a gentle rain, 10 mm. in twenty-four hours. Twelve similar plants were used in the experiment with each fungicide and they were sprayed in the customary way. As soon as the foliage had dried one-half the leaves of each of the plants was removed for analysis and the plants themselves, divided into three sets of four each, were then subjected to the rainfalls mentioned. After the plants had dried the remaining leaves were gathered and analyzed. The results obtained are indicated in table 1.

Guillon and Gouirand (2) have shown that the nature of the surface upon which a fungicide is sprayed may materially modify its adhesiveness and that washes in which the copper occurs as a gelatinous precipitate begin to deteriorate as soon as made. In their experiments the authors used Vitis leaves and glass plates, the latter previously thoroughly cleaned with alcohol, upon which 10 cc. of the fungicide under experiment were placed in drops about 8 mm. in diameter. The copper was determined electrolytically. The results obtained are indicated in table 2.

Castine (3) in his experiments on the adhesiveness of the copper fungicides paid attention to proprietary Burgundy mixtures as well as the washes commonly employed in practice. The author sprayed Vitis leaves and glass plates as uniformly as possible and then divided them into two equal series one of which was analyzed at once, the other after having been artificially rained upon, studies being particularly directed to the effect of age and method of mixing on adhesiveness. The results obtained may be briefly summarized as follows:

TABLE 1

Effect of intensity of rainfall on the relative adhesiveness of copper fungicides

WASH USED	AMOUNT AND DURATION OF RAINFALL		
	17 mm., 22 minutes; copper adhering	15 mm., 6 hours; copper adhering	10 mm., 24 hours; copper adhering
	per cent	*per cent*	*per cent*
2 per cent Bordeaux mixture 1:1	49.1	65.5	86.8
2 per cent Bordeaux mixture 1:0.5	64.7	64.8	83.5
2 per cent Bordeaux mixture 1:1.5 plus 1 per cent aluminum sulphate	67.3	75.5	84.1
2 per cent Bordeaux mixture 1:1 plus 2 per cent molasses	88.8	100.0	100.0
2 per cent Burgundy mixture 1:1.5	80.3	84.1	92.3
1.6 per cent basic acetate of copper	82.8	82.7	89.8

TABLE 2

Effect of character of support and of age of wash on the relative adhesiveness of the copper fungicides

WASH USED	FUNGICIDE SPRAYED				
	On glass; amount of total copper adhering after rain			On *Vitis* leaves; amount of total copper adhering after rain	
	Wash applied			Wash applied	
	At once	After 3 hours	After standing 24 hours	At once	After standing 24 hours
	per cent	*per cent*	*per cent*	*per cent*	*per cent*
2 per cent Bordeaux mixture 1: alkalinity	92	90	82	35.5	32.8
2 per cent Bordeaux mixture plus 1 per cent molasses	74	66	56	28.5	29.8
2 per cent Bordeaux mixture (acid) plus 0.3 per cent gelatin	90	89	86	31.5	28.5
2 per cent Burgundy mixture 1:1.5	80	74	0		
2 per cent Burgundy mixture 1:1.5, sodium bicarbonate being used	80	72	0		
2 per cent Burgundy mixture plus 3 per cent soap	92	82	36	93.6	25.8
2 per cent Burgundy mixture 1:1.5	76		64	37.1	29.3
2 per cent Burgundy mixture plus 3 per cent ammonium carbonate	82		Trace	30.5	Trace
2 per cent Basic acetate of copper	53.7		51.2	33.2	32.9
2 per cent Neutral copper acetate	12.3		11.1	12.7	12.7

Fungicides possessing a coefficient of adhesiveness of 90 to 95 per cent of the copper originally applied are: Alkaline Bordeaux mixture prepared according to the customary American method, Bordeaux mixture and molasses, the formula as originally proposed by Perret being understood, Bordeaux mixture and colza oil (Condemina's formula).

Neutral Bordeaux mixtures possess an adhesiveness of 75 to 80 per cent, while in acid washes the coefficient lies between 50 and 55 per cent.

The coefficient of adhesiveness in Bordeaux mixtures is markedly affected by the method of mixing and may even fall to a negligible quantity as when these fungicides are made from strong solutions. The adhesiveness of Bordeaux mixtures changes little during the first hours following their preparation, Perret's formula being in this respect the most stable, since no marked deterioration occurs within forty-eight hours.

Burgundy mixtures are slightly less adhesive than Bordeaux mixtures. Neutral Burgundy mixtures prepared according to the customary American method possess the highest coefficient, 85 per cent, while, in the case of the alkaline washes, it reaches only 72 to 75 per cent. Burgundy mixtures deteriorate within twenty-four to forty-eight hours and especially rapidly in hot weather.

Basic copper acetate possesses an adhesiveness of 75 to 76 per cent and the wash deteriorates but little on standing.

Neutral copper acetate has an adhesiveness of only 50 to 52 per cent. The addition of kaolin in sufficient quantity will raise the coefficient to 65 to 75 per cent, and ammonia is even more effective, ammoniacal copper acetate possessing a coefficient of adhesiveness of 82 to 83 per cent.

Cuprammonium sulphate possesses an adhesiveness of 56 to 58 per cent; cuprammonium carbonate made from Burgundy mixture 73 to 76 per cent; cuprammonium formate 82 to 83 per cent.

Neutral copper acetate and the cuprammoniums do not deteriorate with age.

Chuard and Porchet (4) describe experiments showing that neutral copper acetate is more adhesive than either Bordeaux or Burgundy mixtures. The authors sprayed shoots of Vitis with a 0.5 per cent solution of neutral acetate of copper. The shoots were then divided into three series, A, B, C. In series A the copper on the leaves was determined as soon as the foliage had dried; in series B the leaves were washed with a heavy artificial rain six hours after the fungicide had been applied; the leaves of series C were washed with a similar rain twenty-four hours after the application of the fungicide. The adhesiveness of the copper in series B amounted to 61.5 per cent; in series C to 81 per cent of the total applied. In another experiment the authors took abscissed leaves, sprayed them with 1 per cent neutral copper acetate, dried them rapidly in sunlight,

and then washed each leaf of one-half the total sprayed forcefully with 500 cc. water one hour later. The copper remaining after this treatment was 12.5 per cent of the total applied.

The authors next obtained data on the amount of copper found on average samples of leaves from eight different vineyards the vines of which had been sprayed with Bordeaux mixture, Burgundy mixture, and neutral copper acetate. The leaves were gathered during the vintage. The data secured is given in table 3.

TABLE 3

Amount of copper in terms of milligrams per leaf found on grape foliage sprayed with Bordeaux mixture, Burgundy mixture and neutral acetate of copper

LOCATION OF VINEYARD	FUNGICIDE USED		
	Bordeaux mixture	Burgundy mixture	Neutral acetate copper
	mgm. Cu.	*mgm. Cu.*	*mgm. Cu.*
Nyon	2.028	2.000	2.340
Aubonne	3.172	2.392	1.720
Morges	2.113	2.550	1.855
Cully	1.104	0.584	0.896
Vevey	1.224	1.444	1.684
Aigle	2.784	2.004	2.172
Orbe	0.764	0.844	1.268
Grandson	0.856	0.636	1.316
Bellerive	1.784	2.556	1.036

The total amount of copper applied per leaf during the course of the season is estimated by the authors to have been:

	mgm. per leaf
Bordeaux mixture	17.7
Burgundy mixture	17.7
Neutral copper acetate	9.9

Whence a simple calculation shows that the adhesiveness of the mixtures varied in the case of Bordeaux mixture between 4.3 to 17.9 per cent; in the case of Burgundy mixture between 3.3 to 14.4 per cent, and in the case of neutral copper acetate between 9.0 to 23.6 per cent.

Kelhofer (5) has made experiments in which he tested the adhesiveness of certain copper fungicides and the effect of the presence of carbon dioxide and ammonium nitrate in water on the solubility of the contained copper.

In the experiments on relative adhesiveness the author used either *Aristolochia sipho* or Vitis leaves which were sprayed in such a way as to obtain a definite amount of copper per square meter of leaf surface. After the fungicide had dried the leaves were cut in two along the midribs

and the halves remaining attached were subjected to rain, either natural or artificial, for a given length of time. Both sets of leaves were then analyzed for copper following the method of Rose.

In a first experiment the author applied the fungicides used at the rate of 327 mgm. copper per square meter and after twenty-four hours removed one half of each of the leaves and subjected the remaining halves to an artificial rain of one hour's duration equal to a fall of water of 20.4 mm. The amount of copper adhering to the leaves after they had been rained upon was in per cent of total originally applied:

	per cent
Copper sulphate	9.7
Cuprammonium sulphate	44.7
Bordeaux mixture 1: alkalinity	60.7
Bordeaux mixture 1: 0.5	67.0
Bordeaux mixture 1: 1	60.7
Bordeaux mixture 1: 1.5	38.1
Burgundy mixture 1: 1.2	68.0
Burgundy mixture 1: 1.4	40.7

In another experiment the author studied the effect of an addition of sugar on adhesiveness. The amount of copper applied per square meter of leaf surface was 250 mgm. and the leaves were subjected to an artificial rainfall of one and a half hours equal to 29.4 mm. of water, the results obtained being as follows:

	per cent
2 per cent Bordeaux mixture 1: alkaline	63.3
2 per cent Bordeaux mixture 1: alkaline plus 0.1 per cent saccharose	53.7
2 per cent Burgundy mixture 1: 1.2	74.8
2 per cent Burgundy mixture 1: 1.2 plus 0.1 per cent saccharose	73.2
1.33 per cent Neutral acetate of copper	38.2
1.33 per cent Neutral acetate of copper plus 0.1 per cent saccharose	41.5
2 per cent Basic acetate of copper	30.2
2 per cent Basic acetate of copper plus 0.1 per cent saccharose	50.6

As rain water may contain both carbon dioxide and ammonium nitrate Kelhofer next performed experiments in order to determine the solvent action of these substances. He sprayed 9 by 12 cm. glass plates with the washes to be studied, 2.5 cc. being used on each plate in the ammonium nitrate tests, and 5 cc. in the case of the carbon dioxide tests. After standing twenty-four hours the plates were placed in distilled water for ten minutes and then transferred either to a 0.02 per cent ammonium nitrate solution in which they were allowed to stand four days, or into water containing 0.2 per cent carbon dioxide for twenty-four hours. The results obtained were as shown in table 4.

Kelhofer (6) has also studied the solubility of Bordeaux mixture con-

taining sugar in water charged with carbon dioxide. The author sprayed glass plates with a 2 per cent Bordeaux mixture 1:0.5 containing 0.05 per cent saccharose and after twenty-four hours, immersed them in water containing carbon dioxide (1 volume water saturated with carbon dioxide plus 2 volumes distilled water) and obtained the result shown in table 5.

In undertaking in our turn a study of the adhesiveness of the copper fungicides we have used the following method.

TABLE 4

Effect of carbon dioxide and ammonium nitrate on the adhesiveness of copper fungicides

FUNGICIDE USED	PLATES IMMERSED IN	
	Carbon dioxide; copper adhering	Ammonium nitrate; copper adhering
	per cent	*per cent*
2 per cent Bordeaux mixture 1:0.25	42.6	52.6
2 per cent Bordeaux mixture 1:0.5	56.1	72.7
2 per cent Bordeaux mixture 1:1	63.3	94.0
2 per cent Burgundy mixture 1:1	24.1	43.7
2 per cent Burgundy mixture 1:1.14	26.6	46.4
2 per cent Burgundy mixture 1:1.4	41.1	67.7

TABLE 5

Effect of the presence of sugar in Bordeaux mixture on the adhesiveness of the mixture when immersed in water containing carbon dioxide

DURATION OF EXPERIMENT	COPPER ADHERING IN BORDEAUX MIXTURE MADE	
	Without sugar	With sugar
	per cent	*per cent*
Plates immersed 3 hours	67.4	66.8
Plates immersed 6 hours	39.5	40.4
Plates immersed 9 hours	32.3	34.4

Plants of Coleus golden bedder, a variety whose foliage wetted readily with all the fungicides used, were spra ed and then allowed to stand forty-eight hours before they were rained on. The plants dried within two hours after they had been sprayed and remained dry until rained upon, that is, the conditions prevailing were suitable for the development of excellent adhesive qualities in all the fungicides used. Fourteen plants or more were taken for each test and not less than three tests were ever made with any one fungicide. Just before the plants were to be rained upon one-half of the leaves that appeared uniformly sprayed were divided by cutting off along the midrib, the left half being invariably taken so as to

insure uniform sampling and eliminate errors due to asymmetry of leaves. Upon being removed the leaf-halves were placed directly in Kjeldahl flasks. As soon as the witness samples had been gathered the plants were placed in a circle beneath an Enterprise sprinkler, which was then turned on and allowed to run half an hour. The rainfall obtained was exceedingly heavy and varied between 4.2 to 17.92 inches per hour. But this variation in the rainfall does not appear to have had any material effect on the result obtained, since as a consideration of table 6 will show, no relation is apparent between amount of rainfall and quantity of copper washed off. After the plants had been rained on the foliage was allowed to dry before

TABLE 6

Relation between intensity of rainfall and adhesiveness of copper fungicides

FUNGICIDE USED	RAINFALL PER HOUR	COPPER (CU) WASHED OFF	FUNGICIDE USED	RAINFALL PER HOUR	COPPER (CU) WASHED OFF
	inches	*per cent*		*inches*	*per cent*
1 per cent Bordeaux mixture 1:1 plus casein	16.88	33.98	1 per cent normal copper acetate	17.92	27.33
	12.38	34.09		14.52	22.44
	9.14	34.47		11.72	24.68
1 per cent Bordeaux mixture 1:1 made with water at 30°C.	12.08	21.21	1 per cent Bordeaux mixture	6.72	56.36
	7.80	33.14		6.28	50.98
	7.06	30.56		4.20	51.21
1 per cent Burgundy mixture 1: alkaline	13.50	12.80	2.5 per cent Pyrox	10.42	37.95
	10.72	20.14		7.68	40.26
	6.50	25.03		6.28	43.66
1 per cent basic copper acetate	15.00	22.68			
	13.70	15.22			
	10.32	21.28			

the remaining halves of the leaves selected for study were cut off and in turn placed in Kjeldahl flasks.

The copper on the leaves was determined by the electrolytic method, the following procedure obtaining after the samples had been flasked as already stated. The flasks were placed in a hot-air oven where they were allowed to remain until the leaves had dried,[1] when they were removed and 10 grams of potassium sulphate together with sufficient sulphuric acid to give the consistency of paste were added to each of them. The flasks were then first gently heated on an electric stove

[1] It is possible to oxidize the leaves without preliminary drying but when this is done frothing proves very troublesome.

until frothing subsided when they were digested over a gas flame for several hours, additional acid being added as required. Digestion was continued until all the carbonaceous matter was destroyed and the solution in the flasks became clear; ammonia was then added to neutrality and the solutions filtered to remove sand and other inert material. The electrolysis was carried out in nitric acid solution with rotating electrode under the usual conditions.

The fungicides used in our experiments were all made with water at, 20°C. unless specifically stated to the contrary and were prepared as follows:

Bordeaux mixtures. The Bordeaux mixtures (1: alkaline[2]), (1: 0.5) (1: 1), (1: 2) were made by adding strong lime to weak copper, the formulae used being as follows:

Bordeaux mixture 1: alkalinity

	parts water
1 part copper sulphate ($CuSO_4.5H_2O$)	85.0
Milk of lime (strong solution)	q. s.
Water to	100.0

Bordeaux mixture 1: 0.5

1 part copper sulphate	85.0
0.5 part calcium oxide	15.0

Bordeaux mixture 1: 1

1 part copper sulphate	85.0
1 part calcium oxide	15.0

Bordeaux mixture 1: 2

1 part copper sulphate	70.0
2 parts calcium oxide	30.0

The Bordeaux mixture to which insoluble arsenicals were added contained 1 per cent copper sulphate and the insecticides were incorporated after the mixtures had been made. On the other hand, in the mixture containing arsenite of soda the arsenical was dissolved in a little water before being added to the wash.

The Bordeaux mixtures containing saccharose (7) was prepared as follows:

	parts water
1 part copper sulphate	5
1 part calcium oxide	85
0.1 part saccharose	10

After the milk of lime and the solution of saccharose had been thoroughly mixed the copper sulphate was added.

[2] Ratios following the name of a fungicide indicate the proportion in which the composing salts were used.

The Bordeaux mixture and ferrous sulphate wash[3] was made in the following manner:

	parts water
1 part copper sulphate	75
1 part calcium oxide	15
1 part ferrous sulphate ($FeSO_4.7H_2O$)	10

After Bordeaux mixture had been made by pouring the milk of lime into the solution of copper sulphate the ferrous sulphate was added.

The Bordeaux mixture and casein wash (10) contained 0.05 per cent casein and was made as follows:

	parts water
1 part copper sulphate	84
1 part calcium oxide	15
1 part casein stock solution	1

The casein stock solution was prepared by dissolving 5 parts casein in 10 parts powdered calcium oxide slacking the mixture and making up with water to 100 parts. One part of this stock solution was then added to Bordeaux mixture prepared by adding the milk of lime to the solution of copper sulphate.

Burgundy mixtures. The following formulae were used in the preparation of the Burgundy mixtures employed.

Burgundy mixture 1: alkalinity

	parts water
1 part copper sulphate	80
Sodium carbonate ($Na_2CO_3.10H_2O$) 18.4 per cent solution	q.s.
Water to	100

Burgundy mixture 1: 1.84

	parts water
1 part copper sulphate	90
1.84 part sodium carbonate	10

In making the mixtures the sodium carbonate was added to the copper sulphate.

Cuprammoniums. In preparing the cuprammoniums, the ammonium hydrate and carbonate were used in sufficient quantity to insure clear solutions.

Copper acetates. It will only be necessary for us to describe the method of preparing the copper acetate washes containing gelatine. The formula

[3] The use of ferrous sulphate for the purpose of increasing adhesiveness was introduced by Selby (8). We have, however, used the method of preparation employed by Waite (9).

(11) used, alike for both the normal and basic copper acetates, was as follows:

	parts water
1 part normal copper acetate 1 part basic copper acetate	99
Gelatine 5 per cent solution	1

The gelatine was dissolved in warm water and the solution allowed to cool to near 20°C. before being used.

From the results of our experiment on the adhesiveness of the copper fungicides the data which is presented in table 7, we draw the following conclusions:

1. Neutral and alkaline Burgundy mixtures are more adhesive than Bordeaux mixtures.

2. Alkaline Burgundy mixture is more adhesive than the neutral wash.

3. The adhesiveness of Bordeaux mixtures is in decreasing order: Bordeaux mixture 1:0.5; Bordeaux mixture 1:1; Bordeaux mixture 1: alkalinity; Bordeaux mixture 1:2, results which are in general agreement with those of previous investigators as a glance at table 8 will show.

4. The effect of the temperature of the water with which Bordeaux mixture is made has but little influence upon its adhesiveness. The opinion that the adhesiveness of a Bordeaux mixture can be judged from a sedimentation test is not therefore as reliable an index as has been thought and it would be more accurate to say that adhesiveness depends on the degree of deterioration rather than on the degree of hydration, that is within the temperature limits 10 to 30°C.

5. Deteriorated Bordeaux mixture 1:1 is more adhesive than deteriorated Burgundy mixture and since the copper precipitate occurs in the form of similar sphaero-crystals in both mixtures it would appear that the increased adhesiveness is due to the lime present in the former.

6. The copper acetates are more adhesive than Bordeaux mixtures, our data being in this respect in accord with the findings of Chuard and Porchet.

7. Ferrous sulphate decreases the adhesiveness of Bordeaux mixture to a very marked degree.

8. The addition of Paris green or arsenite of soda to Bordeaux mixture does not materially change the adhesive properties of the wash; while lead arsenate increases adhesiveness slightly.

9. The adhesiveness of Bordeaux mixture 1:1 is not affected by casein.

10. The addition of gelatine to normal and basic acetate of copper increase the adhesiveness of these salts.

11. Cuprammonium sulphate is very much more adhesive than Johnson's mixture.

TABLE 7

Relative adhesiveness of the copper fungicides

FUNGICIDE USED	AMOUNT OF COPPER (CU) ON LEAF		AMOUNT; COPPER (CU) ADHERING AFTER RAIN	POSITION IN SCALE OF ADHESIVENESS 10 = PERFECT
	Before rain	After rain		
	grams	*grams*	*per cent*	
1 per cent basic copper acetate plus 0.05 per cent gelatine	0.0248	0.0226		
	0.0274	0.0249	90.81	9.1
	0.0326	0.0296		
1 per cent normal copper acetate plus 0.05 per cent gelatine	0.0436	0.0374		
	0.0505	0.0439	86.61	8.7
	0.0495	0.0430		
1 per cent basic copper acetate	0.0506	0.0429		
	0.0313	0.0242	80.88	8.1
	0.0343	0.0270		
1 per cent Burgundy mixture 1: alkalinity	0.1112	0.0888		
	0.0959	0.0789	79.38	7.9
	0.0751	0.0563		
1 per cent normal copper acetate	0.0575	0.0446		
	0.0322	0.0234	75.80	7.6
	0.0320	0.0241		
1 per cent Burgundy mixture 1: 1.84	0.0289	0.0201		
	0.0506	0.0373	75.32	7.5
	0.0614	0.0508		
	0.1037	0.0761		
1 per cent Bordeaux mixture 1: 1 plus 0.5 per cent lead arsenate	0.0522	0.0372		
	0.0566	0.0441	74.49	7.4
	0.0534	0.0396		
1 per cent Bordeaux mixture 1: 1 plus 0.1 per cent saccharose	0.0497	0.0374		
	0.0436	0.0306	72.98	7.3
	0.0333	0.0245		
1 per cent Bordeaux mixture 1: 1 prepared with water at 30°C.	0.0698	0.0550		
	0.0995	0.0691	71.23	7.1
	0.0802	0.0536		
1 per cent Bordeaux mixture 1: 1 prepared with water at 10°C.	0.0227	0.0164		
	0.0618	0.0429	70.56	7.1
	0.0928	0.0658		
1 per cent Bordeaux mixture 1: 1 plus 0.25 per cent sodium arsenite	0.0502	0.0331		
	0.0512	0.0371	68.85	6.9
	0.0498	0.0339		

TABLE 7—*Concluded*

FUNGICIDE USED	AMOUNT OF COPPER (CU) ON LEAF		AMOUNT; COPPER (CU) ADHERING AFTER RAIN	POSITION IN SCALE OF ADHESIVENESS 10 = PERFECT
	Before rain	After rain		
	grams	*grams*	*per cent*	
1 per cent Bordeaux mixture 1:0.5	0.0698	0.0437	67.92	6.8
	0.0139	0.0082		
	0.0251	0.0177		
	0.0609	0.0457		
1 per cent Bordeaux mixture 1:1	0.0233	0.0140	67.35	6.7
	0.0751	0.0532		
	0.0730	0.0477		
	0.0443	0.0303		
1 per cent Bordeaux mixture 1:1 plus 0.5 per cent Paris green	0.0190	0.0127	66.37	6.6
	0.1182	0.0731		
	0.0956	0.0686		
1 per cent Bordeaux mixture 1:1 plus 0.05 per cent casein	0.0481	0.0317	65.81	6.6
	0.1427	0.0942		
	0.0882	0.0578		
2.5 per cent Pyrox (strength used equivalent in copper to 0.15 per cent Bordeaux mixture	0.0142	0.0080	61.21	6.1
	0.0149	0.0089		
	0.1046	0.0649		
1 per cent Bordeaux mixture 1: alkalinity	0.0185	0.0094	59.95	6.0
	0.0357	0.0169		
	0.0273	0.0174		
	0.0811	0.0538		
0.25 per cent Cuprammonium sulphate	0.0061	0.0034	58.46	5.8
	0.0048	0.0028		
	0.0087	0.0052		
1 per cent Bordeaux mixture 1:2	0.0457	0.0232	57.36	5.7
	0.0821	0.0543		
	0.0860	0.0451		
1 per cent Bordeaux mixture 1:1 deteriorated	0.0621	0.0271	46.88	4.7
	0.0455	0.0222		
	0.0512	0.0251		
0.25 per cent Johnson's mixture	0.0094	0.0036	36.26	3.6
	0.0081	0.0029		
	0.0075	0.0027		
1 per cent Bordeaux mixture 1:1 plus 1 per cent ferrous sulphate	0.0818	0.0257	25.77	2.6
	0.0822	0.0158		
	0.0305	0.0086		
1 per cent Burgundy mixture 1:1.84 deteriorated	0.0302	0.0064	21.82	2.2
	0.0493	0.0114		
	0.0359	0.0075		

12. The proprietary copper fungicide and arsenical insecticide Pyrox possesses a fair degree of adhesiveness, but is noticeably inferior to its equivalent 1 per cent Bordeaux mixture 1:1 plus 0.5 per cent arsenate of lead.

In closing we should perhaps remind our reader that adhesiveness is not the only consideration that governs the value of a fungicide in practice. Climatic conditions prevailing at the time the fungicide is applied affect the adhesive properties of the wash, and the prevailing climatic regimen of a region or even locality must be considered in coming to a

TABLE 8

Comparative adhesiveness of Bordeaux mixtures as determined by different workers

STRENGTH OF SOLUTION IN COPPER SULPHATE	RATIO; COPPER SULPHATE CALCIUM OXIDE	ADHESIVENESS	AUTHOR
per cent		*relative nos.*	
2	1:0.5	100.0	Girard
2	1:1	75.6	
2	1:0.2	58.6	Guillon and Gouirand
2	1:0.3	67.8	
2	1:0.2	58.6	Gastine
2	1:0.3	93.0	
2	1:0.5	100.0	
2	1:0.3	90.4	Kelhofer
2	1:0.5	100.0	
2	1:1	90.4	
2	1:1.5	56.7	
1	1:0.3	88.1	The authors
1	1:0.5	100.0	
1	1:1	99.0	
1	1:2	84.3	

decision regarding the choice of a fungicide. The wash used must not be toxic to the plant to be protected nor should its physical properties be such as to place the plant below the optimum conditions for the growth of the epigean organs. The active principle of the wash must be effective; that is the unit copper must have a protective value consistent with the degree of tolerance of the fungus from which protection is sought. The parasite must also be considered in coming to a decision. In a word, adhesiveness should not be allowed to overshadow all other considerations.

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TRANSMISSION OF THE VIRUS OF BEAN MOSAIC IN SEED AND OBSERVATIONS ON THERMAL DEATH-POINT OF SEED AND VIRUS

DONALD REDDICK AND V. B. STEWART[1]

In recent publications the writers have stated[2] that the virus of bean mosaic is transmitted in the seed. No evidence of this has been presented, however, and it is the purpose of the present paper to present the evidence on which the statements are based as well as to record some tests made to destroy the virus in the seed by thermal treatments.

The mosaic disease of beans has many points in common with the better known mosaic of tobacco but there are two points of divergence worthy of special mention in connection with the present study. In the first place the writers have never succeeded in producing infection with expressed juice of diseased plants either with sufficient regularity or in sufficient quantity to feel sure that the occasional plants showing the disease had not become infected in some other way. A great many trials have been made with hypodermic syringe, by placing droplets of freshly expressed juice on leaves and by rubbing leaves with the fingers after dipping them in the juice. With a very fine needle it is possible to inject into a leaf a large drop of juice which can be seen to spread through the tissues to the extent of 1 sq. cm. or more. The area takes on a watery appearance, indicating that the intercellular spaces are filled. Some cells are pierced by the needle and a slightly sunken condition of the area which appeared watery is evident often for several days, thus indicating that tissues have been broken and assuring that the injected juice has come in contact with living protoplasm. Parallel with all such experiments, plants have been inoculated by rubbing vigorously the under sides of the juvenile leaves with diseased leaves rolled together and crushed with the fingers. In the latter case a high percentage of infection has been obtained but in the former it is impossible to say with certainty that any infection has resulted.

The other point of divergence of the mosaic of beans from that of tobacco is that whereas the virus of tobacco mosaic is to be found in

[1] Doctor Stewart was associated in all of the work reported here except the seed treatments. The paper was prepared after his death.

[2] Phytopath. **7:** 61. 1917; **8:** 530-534. 1918.

practically all parts of the plant except the seed,[3] the virus in bean mosaic is in the seed as well as in other parts (evidence of the occurrence of the virus in bean roots is not entirely conclusive at present). Before presenting the evidence that this is true, certain accessory facts, determined by experiment, should be stated which tend to show that the easiest method of demonstrating seed transmission of the virus is likewise a reliable one.

Thousands of bean plants have been inoculated in the greenhouse and with practically every set of tests some plants have been retained as controls on the experiment. In looking over the records it now seems doubtful whether a single control plant has ever acquired the disease. In some of the earlier work occasional controls have been recorded as showing the disease but it is now thought that at that time the writers were not sufficiently acquainted with the symptoms of the disease to detect affected plants in the seedling stage, and that plants not inoculated but held as a check on the experiment and recorded as contracting the disease, in reality came from diseased seed.

Another point of importance in this connection is the fact that the disease is not readily communicated from plant to plant. Often a single plant in a pot containing 2 or more plants has been inoculated by rubbing. No care was taken to avoid contact with the other plants either at the time of inoculation or later. Under such condition, healthy and diseased plants have grown to maturity with no indication of a transfer of the disease. Likewise seeds from healthy plants have been planted in pots with diseased ones. Such plants have invariably come up healthy and have remained so. Finally, freshly plucked leaves from mosaic diseased plants were arranged in pots of earth in such a way that the radicle of germinating seeds must pass through them in from twenty-four to forty-eight hours. Excised leaves kept in a shady place had been found by trial to retain the virus in viable condition for that length of time. The plants grew and remained healthy.

The conditions stated in the preceding paragraphs make it evident that the disease is not readily communicated from plant to plant in a greenhouse at Ithaca. If, therefore, seeds from diseased and from healthy plants are disinfected externally, are planted in the usual way and then some of them develop the mosaic disease, the evidence of internal infection would seem sufficient. This has been done on several occasions. The seeds were disinfected by immersion for four hours in bleaching

[3] Allard, H. A. Distribution of the virus of the mosaic disease in capsules, filaments, anthers and pistils of affected tobacco plants. Jour. Agric. Res. **5**: 251–256. Pl. 23. 1915.

powder solution as proposed by Wilson.[4] Treatment for this length of time is sufficient to accomplish disinfection except in cases where fungi or bacteria have previously gained access to the seed. This was demonstrated by washing treated seeds in sterilized water and planting them in tubes of sterilized nutrient agar. Treatment of bean seed for four hours in the chlorid of lime results in the death of some seeds or in retarded germination, indicating that this interval of time is near the maximum for beans. Seeds so treated have been planted and in one lot of about 100 plants something over 50 per cent showed unmistakable mosaic. This is in accord with the behavior of the variety tested when untreated seeds are used. Some other varieties which throw a higher percentage of mosaic diseased plants when seeds from diseased plants are used, were tested similarly in small lots of 8 or 10 seeds each. The tests confirmed the conclusion already reached.

In the light of present knowledge these tests seem sufficient to demonstrate the internal nature of the causal agent. Before all these facts were known, however, certain other experiments were undertaken which may be regarded as more rigidly controlled but which lack the advantage of numbers. Seeds were disinfected in the usual way and were then rinsed in sterilized water and transferred aseptically to very large test tubes which were plugged with cotton and contained sterilized soil. Bean plants do not grow very satisfactorily under such conditions and of 18 or 20 plants so grown only 5 or 6 could be pronounced unmistakably mosaic. It is enough, however, to indicate the internal nature of the virus.

If one reviews the literature of the virus diseases, of which there are about fifty known cases, it is surprising to find how regularly the virus is killed or inactivated at about 60°C. The recent work of White[5] shows that the medium in which the virus is present alters the thermal death-point as much as ten degrees. Thus the virus of sacbrood of bees in water is killed by immersion for ten minutes at a temperature of 58°, whereas, if it is suspended in honey its death-point for ten minutes exposure is 70 to 71°. Nevertheless, it seemed worth while, considering the similarity of bean mosaic to virus diseases in general, to determine as nearly as possible the thermal death-point of the virus when suspended in the concentrated medium of the bean seed. Preliminary trials showed that if it is killed or inactivated at 70° by exposure for ten minutes or even for twenty minutes a ready means of control of the disease would be at hand. Accordingly seeds from diseased plants were baked at various

[4] Wilson, James K. Calcium hypochlorite as a seed sterilizer. Amer. Jour. Bot. **2**: 420–427. 1915.

[5] White, G. F. Sacbrood. U. S. Dept. Agric. Bull. 431. 54 p. 33 fig. 1917.

temperatures and for varying lengths of time as shown in table 1. Three varieties of beans have been tested (Navy pea, Red kidney and an unnamed variety), but their behavior is substantially alike and only one set of experiments with one variety is shown in the table.

TABLE 1

Experiments with seed of Navy Pea beans to determine the effect of baking on the viability of the seed and on the virus of the mosaic disease in the seed

TEMPERATURE	DURATION	GERMINATION	MOSAIC	REMARKS
°C.	*minutes*	*per cent*	*per cent*	
60	60	90	90	
	90	80	80	Weak plants
	120	80	75	Weak plants
	180	90	40	Very weak plants
	24 hrs.	70	66	
65	60	80	75	
	90	60	83	
	120	70	85	
	180	60	100	Weak plants
70	20	90	70	
	30	60	66	
	40	40	75	
	50	50	100	Very weak plants
	60	10	?	Very weak plants
	90	50	80	Very weak plants
75	10	90	80	
	20	80	66	
	30	70	75	Very weak plants
	40	50	66	Very weak plants
80	10	50	20	
	20	0	0	
90	10	0	0	
Untreated . (average of 80 seeds)		85	71	

General survey of the table shows that in every case where seeds survived the treatment, the virus of mosaic survived also. More critical examination of the table shows some unexpected variations. These are readily explained. In the first place the percentages of this example are based on single plantings of 10 seeds each. The reduced germination for

long exposure of the seeds baked at temperatures above 60°, however, has been general in all the trials and may be regarded as significant. In many cases plants died in the seedling stage or made very poor growth. Such plants are recorded under the column "germination" but they do not figure in the record of "mosaic." Weak plants usually do not show clear cases of mosaic and in the table only those plants are recorded which showed unmistakable symptoms of the disease. Some indication of the effect of the treatment on the vitality of the seed is indicated in the column headed "remarks."

TABLE 2

Experiments with seed of Navy Pea bean to determine the effect of hot water on the viability of the seed and on the virus of the mosaic disease in the seed

TEMPERATURE	DURATION	GERMINATION	MOSAIC	REMARKS
°C.	*minutes*	*per cent*	*per cent*	
60	5	50	60	
	10	10	?	
	15	20	100	
	20	10	100	
	25	20	50	
	30	0	0	
65	5	50	50	Weak plants
	10	30	66	
	15	40	50	
70	5	30	66	
	10	20	50	
	15	10	100	
	20	0	0	
Check (cold water)	5	90	66	
	10	80	66	
	15	100	70	
	20	100	90	
	25	90	30	Very weak plants

Moist heat also was tried on the variety Navy Pea, both with and without preliminary soaking of feed for one hour in tepid water. Flasks of water were placed in an incubator and brought to the required temperature. The seeds were dropped into the hot water and left for various intervals of time after which the water was poured off and the seeds planted at once in beds in the greenhouse.

The germ of the seed is killed at much lower temperature under moist conditions than under dry but the thermal death-point of the seed is as

low as that of the causative agent of mosaic. The data are shown in table 2. Even had a difference been found there lies here little of importance. Not only does the seedcoat slip after a short interval of soaking in water but the work of Kidd and West[6] shows that soaking bean seeds in water for six hours is very detrimental to later development. Even in the case of previous soaking for only one hour it seems from the appearance of plants used in the above experiments that some such detrimental effect had occurred.

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[6] Kidd, Franklin and Cyril West. Physiological predetermination: The influence of the physiological condition of the seed upon the course of subsequent growth and upon the yield. I. The effect of soaking seeds in water. Ann. Appl. Biol. **5**: 1–10. Pl. 1–2. 1918.

OBSERVATIONS ON THE RELATION OF INSECTS TO THE DISSEMINATION OF CRONARTIUM RIBICOLA[1]

WALTER H. SNELL

INTRODUCTION

The observations of Gravatt and Marshall,[2] and Gravatt and Posey[3] on insects and other Arthropoda as carriers of urediniospores and teliospores of *Cronartium ribicola* Fischer in the greenhouse and on the part played by the larvae of the gypsy moth, *Porthetria dispar L.*, in the spread of blister rust spores in the field, show that insects may, whether accidentally or otherwise, carry large numbers of *C. ribicola* spores on their bodies or in their excreta. Certain further observations made during 1917 and 1918 can now be recorded.

INSECT CARRIERS OF AECIOSPORES[4]

In June, 1917, a collection was made of the insects found on or near *Cronartium ribicola* cankers and of other insects found in a generally infected white pine woodlot at Kittery Point, Maine, by G. F. Gravatt and G. B. Posey. At the time of collection each insect was placed in a number 00 gelatin capsule, the capture of the insect being carried on as carefully as possible to avoid picking up any of the blister rust spores which were probably adhering to the white pine bark at all times. Some of the insects were collected directly from the blister rust pustules where they had been feeding. The data of the collections is given in table 1.

In the cases of the small insects or larvae (nos. 1, 2, and 33 to 39 inclusive of table 1) examination for spores was made by direct mount and count. It is, of course, obvious that this method gives only an approximately correct estimate, because it is impossible to see both

[1] This paper is issued as a part of the cooperative investigations carried out jointly by the Bureau of Plant Industry and the Bureau of Entomology on the relation of insects to the spread of plant diseases.

[2] Gravatt, G. F. and Marshall, R. P. Arthropods and gastropods as carriers of Cronartium ribicola in greenhouses. Phytopathology **7:** 368–73, 3 tables. 1917.

[3] Gravatt, G. F. and Posey, G. B. Gypsy-moth larvae as agents in dissemination of the white pine blister rust. Jour. Ag. Res. **12:** 459–462. 1918.

[4] Account is also taken of the carrying of spores by sowbugs, spiders, slugs and daddy longlegs.

TABLE 1

AGENT	NUMBER OF SPORES	COLLECTION DATA
Crustaceans		
30 Porcellio laevis Lat	16,504	At base of P. strobus infected with C. ribicola
31 Porcellio laevis Lat	6,510	At base of P. strobus infected with C. ribicola
32 Porcellio laevis Lat	400	Near canker of C. ribicola on P. strobus
Spiders		
41 Xysticus ferax (?) Hentz (spider)	0	Near C. ribicola canker on P. strobus
22 A Phalangid sp. (daddy longlegs)	350	At base of P. strobus infected with C. ribicola
23 A Phalangid sp (daddy longlegs)	250	Near C. ribicola canker on P. strobus
Insects		
Collembola (springtails)		
1	2	On C. ribicola canker on P. strobus
2	2	Near C. ribicola canker on P. strobus
Coleoptera		
Elateridae (click beetles)		
4 Corymbites triundulatus Rand	800	On C. ribicola pustule on P. strobus
5 Corymbites aeripennis Kirby	0	On grass in infected area
17 Melanotus sp	4,000	On grass in infected area
18 Melanotus sp	5,300	On C. ribicola canker on P. strobus
Lampyridae (lightning bugs)		
7 Ellychnia corrusca L	140	On P. strobus infected with C. ribicola
8 Ellychnia corrusca L	1,300	On P. strobus infected with C. ribicola
Scarabeidae (scarabeid beetles)		
40 Serica sericea Illiger	30	Feeding on Ribes rubrum one mile from infected area
Chrysomelidae (leaf beetles)		
11 Clyptoscelis pubescens Illiger	1,050	On ground, 3 feet from base of P. strobus infected with C. ribicola

Lathridiidae (minute brown scavenger beetles)		
16 Melanophthalma gibbosa Hbst.	0	On C. ribicola canker on P. strobus
Otiorhynchidae (short snout beetles)		
19 Panscopus sp.	800	On C. ribicola canker on P. strobus
20 Panscopus sp.	200	At base of P. strobus infected with C. ribicola
21 Panscopus sp.	0	Caught on fly paper exposed in infected area
Curculionidae (curculios)		
3 Conotrachelus nenuphar Hbst. (plum curculio)	14,832	Feeding on C. ribicola pustule on P. strobus
24 Pissodes strobi Peck. (pine weevil)	100	On C. ribicola pustule on P. strobus
25 Pissodes strobi Peck. (pine weevil)	1,000	Near C. ribicola canker on P. strobus
26 Pissodes strobi Peck. (pine weevil)	0	Near C. ribicola canker on P. strobus
27 Pissodes strobi Peck. (pine weevil)	400	On C. ribicola canker on P. strobus
28 Pissodes strobi Peck. (pine weevil)	0	Near C. ribicola canker on P. strobus
Scolytidae (bark beetles)		
6 Dendroctonus valens (?) Lee	35	At base of P. strobus infected with C. ribicola
12a Gnathotrichus materiarius Fitch	0	Working in roots of P. strobus infected with C. ribicola
12b Ips caelatus Eich.	0	Working in roots of P. strobus infected with C. ribicola
14 Ips caelatus Eich.	0	Near P. strobus
15 Ips pini Say	50	Feeding (?) in C. ribicola pustule on P. strobus
29 Pityogenes hopkinsi Swaine	0	On ground near P. strobus
Lepidoptera		
Liparidae (tussock moths)		
33 Porthetria dispar L. (larva) Gypsy moth	2,000	On C. ribicola pustule on P. strobus
34 Porthetria dispar L. (larva)	1,000	On C. ribicola pustule on P. strobus
35 Porthetria dispar L. (larva)	1	Near C. ribicola canker on P. strobus
36 Porthetria dispar L. (larva)	500	Near C. ribicola canker on P. strobus
37 Porthetria dispar L. (larva)	12	Near C. ribicola canker on P. strobus
Diptera		
9 Fucellia maritima Hal.	0	On grass in infected area
10 Leptis mystacea Macq.	500	At base of P. strobus infected with C. ribicola
Unidentified		
13 Unidentified insect	600	On C. ribicola canker on P. strobus

sides of the insect when it is mounted beneath a cover glass. The results obtained, however, give a fair idea of the number of spores present. In the case of the gypsy moth larvae, it was found that the aeciospores were in some cases literally encrusting the bodies at the bases of the hairs. In one case the larva moulted in the capsule and on making the count it was found that the moult was thickly studded with spores while the larva had about ten spores upon its body.

Most of the insects, however, had to be treated in a different manner in order to prepare them for examination. The spores were removed from their bodies by a double washing. Each insect was shaken vigorously in 10 to 15 cc. of distilled water and then subjected to a strong fine stream of water from a needle pipette. This latter washing was for the purpose of removing all the spores that could possibly be dislodged by any washing process. It is clear that many spores probably still remained sticking to the body of the insect after the washing had been completed. The wash water was placed in a centrifuge to drive the sediment to the bottom of the tube. The surface water was then decanted, leaving 1 cc., which contained all the sediment of the wash water. The method of counting the spores in the wash was essentially that of other investigators; i.e., a small fraction of the total amount was mounted and every spore present counted. One drop of the concentrated water was usually enough to give indication of the number of spores present if the wash water was carefully and thoroughly agitated. By calibrating the pipette used it was possible to arrive at the number of drops per cubic centimeter which a given pipette would deliver. Therefore, by counting the spores in one drop and multiplying the result by the number of drops per cubic centimeter for the particular pipette used, an approximate estimate could be obtained of the number of spores in the 1 cc. of concentrated wash water. It was found that a 22 mm. square cover glass just about covered the drops used, and accordingly, the count was made by working back and forth across the surface of the cover glass. The results of the examination of the wash water are shown in table 1.[5]

The inclusion of the Isopod *Porcellio laevis* (sowbug), the spider *Xysticus* and the two species of *Phalangids* (daddy longlegs) in the table seemed advisable because they were common visitors to the pines. It will be noted that *Porcellio* carried large numbers of aeciospores on its body, and that these observations confirm those of Gravatt and Marshall (loc. cit.) on the part played by Isopods in the spread of *Cronartium ribicola* spores in the greenhouse. The sowbug is cosmopolitan and it should be counted among the possible natural insect spreaders of *Cronartium ribicola*. The same general statement will apply to the *Phalangids*.

[5] Dr. Reginald H. Colley made the examination of the insects and prepared the data in table 1.

The writer is indebted to Dr. Dwight Pierce of the Bureau of Entomology for the identification of nos. 1, 2, 3, 19, 20, 21, 24, 25, 26, 27, and 28; to Messrs. Schwarz and Barber of the same Bureau for the identification of nos. 4, 5, 6, 7, 8, 11, 16, 17, 18, and 40; to Mr. Clarence B. Shoemaker of the United States National Museum for the identification of nos. 22, 23, and 41; to Miss Boone of the United States National Museum for the identification of nos. 30, 31 and 32; to Dr. A. D. Hopkins of the Bureau of Entomology for the identification of nos. 12, 14, 15 and 29; and to Dr. J. M. Aldrich of the Bureau of Entomology for the identification of nos. 9 and 10.

INSECT CARRIERS OF UREDINIOSPORES AND SPORIDIA

The observations on the relation of insects to the spread of the other spore forms of *C. ribicola* were made in 1918 in Essex County, New York, and refer for the most part to the urediniospores. The purpose of the study was threefold: to gain information as to the kinds and relative number of insects and other animals found on Ribes bushes, infected or healthy; to find what kinds and how many carried urediniospores and teliospores; and to learn whether or not insects or other animals could spread the disease. The major part of the work was gathering the visitors to the Ribes bushes and examining them for urediniospores; the remainder, inoculation of Ribes by means of spore-carrying insects.

Frequenters of Ribes bushes were collected more or less consistently all during the season of 1918. The "frequenters" (here used to mean insects for the most part, but including slugs and spiders) were killed immediately upon collection and each one transferred to a separate vial. They were examined in the field laboratory shortly after being collected. No attempt was made to estimate the number of spores carried, except as to relative scarcity or abundance. The species captured upon or near Ribes bushes and the presence or absence of spores upon each are noted in table 2.

Over a hundred different species of insects were captured on Ribes bushes. Some of these were taken only once and others were not common, but many of the forms, especially the Hemiptera, occurred in large numbers. Both adults and larvae were present. Among the most common, especially early in the season, were the many species of leaf-eating larvae, chiefly measuring worms (*Geometridae* of the order *Lepidoptera*). Their importance in spore dissemination may be questioned on the ground that these larvae eat the leaves and thus undo some of their own mischief; but they crawl more or less over the leaves and even go from bush to bush. Stinkbugs (*Pentatomidae* of the order *Hemiptera*) were

TABLE 2

List of insects and other animals collected upon Ribes bushes in Essex County, N. Y., in 1918, showing those which were found to bear urediniospores and sporidia of Cronartium ribicola. X in the column headed "Presence of Spores" denotes urediniospores found: 0 that no spores were found; the finding of sporidia is made the subject of a special note

ANIMALS AND INSECTS COLLECTED	PRESENCE OF SPORES
Molluscs	
Slugs, mostly small ones, found early in the season	X
Arachnids	
Spiders and daddy longlegs	X
Insects	
Neuroptera	
80a Chrysopa oculata Say. (lace-wing)	X
80b Chrysopa albicornis Fitch. (lace-wing)	X
Orthoptera	
Acrididae (locusts)	
15d Melanoplus femur-rubrum DeG. (red-legged grasshopper	0
45a Orphulella speciosa Scud	X
45b Orphulella speciosa Scud. (nymph)	X
Gryllidae (crickets)	
136 Oecanthus niveus DeG. (snowy tree cricket)	X
Hemiptera	
Membracidae (tree hoppers)	
55b, 76 Ceresa bubalus Fab (buffalo tree hopper)	X
210, 55a Ceresa diceros Say. (2 horned tree hopper)	X
48 Ceresa taurina Fitch	X
83 Ceresa turbida Godg	X
46 Tettigonia gothica Sign	0
111, 206 Publilia concava Say	0
31 Campylenchia curvata Fabr	0
Cercopidae (spittle insects)	
28b Lepyronia 4-angularis Say	0
28a Aphrophora 4-notata Say	0
30a, 30b Aphrophora saratogensis Fitch	0
132 Aphrophora parallela Say	X
56a, 56b Ptyelus spumarius ?	0
Jassidae (leaf hoppers)	
87a, b, c, d Diedrocephala coccinea Forst	X
84a Xerophloea viridia	X
84b Typhlocyba rosae Linn	X
91 Typhlocyba querci Fitch. var. bifasciata Gill	0
23a Gypona flavilineata Fitch	0
21 Idiocerus nervatus Van. D	0
21a Idiocerus lacrymalis ?	0
29 Deltocephalus inimicus Say	0
123 Eutettix strobi Fitch	0
63 Dicraneura sp. ?	0
Aphididae (aphids)	
12 Aphis houghtenensis Troop	X
38, 98 Aphis spp	0

TABLE 2—*Continued*

ANIMALS AND INSECTS COLLECTED	PRESENCE OF SPORES
Pentatomidae (stink bugs)	
78a Euchistus fissilis Uhl	X
78b Euchistus tristigmus Say	X
201 Euchistus tristigmus (nymph)	X
Euchistus euchistoides Voll	X
78d Banasa dimidiata Say	X
79d Podisus maculiventris Say	X
78c Podisus placidus Uhl	X
Lygeidae (chinch bugs)	
23b Nysius angustatus Uhl. (false chinch bug)	0
52 Lygrocoris contractus Say	X
Coreidae (squash bugs)	
77b, 77c Neides muticus Say	0
Nabidae (damsel bugs)	
62 Coriscus sp	X
Reduviidae (assassin bugs)	
77a Diplodus luridus Stal. ? (nymph)	X
Phymatidae (ambush bugs)	
32b Phymata wolffi Stal	0
32a Phymata wolffi Stal. (nymph)	0
Capsidae (leaf bugs)	
17a Diaphnidia pellucida Uhl	0
137 Plagiognathus politus Uhl	X
51 Lopidea media Say	X
93 Compsocerocoris annuliconnis Reut	0
83, 113 Megalocoelus coagulatus Uhl. ?	0
131 Lygus pratensis Linn. (tarnished plant bug)	0
Lepidoptera	
Pieridae (pierids)	
85 Pieris rapae Linn. (cabbage butterfly)	0
Arctiidae (tiger moths)	
82 Eubaphe aurantiaca Hubn	0
2, 7 Diacrisia virginica Fab. (larva	X
6 Halisidota carvae Harris (larva)	X
8 Hypantria textor Harris (larva)	0
145 Diacrisia acraea Dru. (larva)	X
Liparidae (tussock moths)	
38a, 39a Porthetria dispar. L. (gypsy moth larva[6])	X
Noctuidae (owlet moths)	X
10 Apatella americana Harris (larva)	X
Gelechiidae	
95 Aristotelia roseosuffusella Clem	0
Notodontidae (prominents)	
4, 142 Datana ministra Dru. (larva)	X
5, 147 Schizura concinna S & A (larva)	X
Geometridae (measuring worms)	
1 and several other numbers Larvae found early in season	X
Saturniidae (silk worms)	
143 Automeris io Fab. (larva)	X

TABLE 2—*Continued*

ANIMALS AND INSECTS COLLECTED	PRESENCE OF SPORES
Pyrallidae	
81 Crambus vulvivagellus Clem.	0
Pterophoridae (plume moths)	
12h Larva unidentified	0
Tortricidae (leaf rollers, bud borers)	
82 Adult not identified	0
Cochlidiidae	
148 Euclea indetermina Boisd.	0
40, 81a, 81b, 88, 89 Unidentified	0
Diptera	
Culicidae (mosquitoes)	
86a Culex canadensis Theob. (mosquito)	X
86b Aedes abfichtii F & Y.	X
Asilidae (robber flies)	
34 Tolmerus notatus Wied. ?	0
Dolichopodidae (long-legged flies)	
37 Dolichopus variabilis Loew	0
Muscidae (house flies)	
202 Pseudopyrella cornicus Fab.	0
Oscinidae	
36 Chlorops assimilis Macq.	0
Drosophilidae (pomace flies)	
107 Drosophila ampelophila Loew	0
38, 39, 94 Not identified	0
124 Not identified	X
Coleoptera	
Chrysomelidae (leaf beetles)	
54 Coptocycla significa Hbst. (tortoise beetle)	X
112 Psylliodes punctulata ? Melsh. (flea beetle)	0
57, 100, 138, 140, 144 Chaetocnema confinis Crotch (flea beetle)	0
123 Diabrottica vittata Fab. (striped cucumber beetle)	0
53 Crytocephalus quadrimaculatus Say. (leaf beetle)	X
35 Bassareus formosus Melsh.	0
Scarabeidae (scarabeid beetles)	
55 Macrodactylus subspinosus Fab. (rose beetle)	X
Buprestidae (metallic wood borers)	
96 Agrilus ruficollis Fabr. (red-necked cane borer)	0
Lathridiidae (minute brown scavenger beetles)	
57 Melanophthalma cavicollis Mann. ?	X
Endomychidae (handsome fungus beetles)	
209 Endomychus biguttatus Say	0
Coccinellidae (lady beetles)	
56 Brachyacantha 10-pustulata Melsh.	X
Otiorhynchidae (scarred snout beetles)	
34 Otiorhynchus ovatus Linn. (ovate snout beetle)	0
33, 58, 90 Unidentified	0
Hymenoptera	
Tenthredinidae (sawflies)	
135 Schizocerus ebenus Nort. (sawfly)	X
Larvae of Selandriinae	X

TABLE 2—*Concluded*

ANIMALS AND INSECTS COLLECTED	PRESENCE OF SPORES
Chalcididae (chalcis flies)	
117 Pteromalus ?	0
Pelecinidae	
203 Pelecinus polyturator Dru	X
Formicidae (ants)	
60b Camponotus marginatus var. minutus Emery (ant)	X
Myrimicidae (ants)	
60a Myrmica graminicola americana Emery (ant)	X (sporidia)
143 Gorytes phaleratus Say (ant)	X (sporidia)
Pemphredonidae	
118 Pemphredon inornatus Say (digger wasp)	0
Halictidae (sweat bees)	
35a, 39, 126, 127, 128, 129	0

very common in various stages of their development all summer long on all species of Ribes. A number of species of the leaf and tree hoppers (*Jassidae* and *Membracidae* of the *Hemiptera*) were common, several species being found at a time through the season. The Jassids *Diedrocephala coccinea* and *Typhlocyba rosae* could be found at any time on *Ribes cynosbati* or *R. rotundifolium*, and individuals of the various species of *Ceresa* were very abundant on *R. nigrum*. Rosebugs were numerous on all species of Ribes early in the summer, as were aphids on cultivated bushes in June and July. Mosquitoes were found on the lower surfaces of the leave and were especially abundant in rainy weather.

The writer is indebted to Mr. D. M. Benedict of the New York State College of Forestry at Syracuse, for collecting certain of the insects late in the season; to Dr. A. L. Quaintance of the Office of Deciduous Fruit Insect Investigations at Washington for having the following insects identified: nos. 2 to 10 inclusive, 12h, 81, 82, 85, 86, 142, 143, 145, 146, 147, 148, by Mr. Dyar—no. 11 by Mr. Rohwer—no. 12 by Dr. Baker—no. 1 by Mr. Heinrich; to Dr. E. D. Ball, State Entomologist for Iowa for the identification of tree and leaf hoppers nos. 21a, 46, 48, 84, 84a, 87, 210, 55a; to Mr. D. B. Young, assistant to Dr. E. P. Felt of the New York State Museum at Albany who identified the remainder; and to Dr. L. H. Pennington of the New York State College of Forestry for the kindness of having a large majority of the insects identified during the writer's absence from the field work in the latter part of the season.

Urediniospores were found on many individuals of forty different species, quite regularly on slugs and insects taken on infected bushes, particularly those which crawled over the under side of the leaves, like caterpillars, stinkbugs, leaf hoppers, etc. Spores were very abundant upon caterpillars and slugs. The former were observed crawling over the lower side of the leaves leaving a trail of urediniospores behind them—clusters easily visible with a 15 × hand lens. Small slugs sometimes became so covered with spores that they had a distinct orange color. Clumps of spores upon their bodies were visible to the naked eye, as was the trail of spores left behind them upon the leaves.

The adult insects and larvae of the *Hemiptera* bore urediniospores in varying numbers. Bristly-legged insects like the rosebugs commonly carried large numbers of spores on their legs. Species of the tree hopper *Ceresa* and other insects caught on infected black currant bushes bore an abundance of spores because of the abundance of spore material upon the diseased leaves. On other insects, the number of spores varied with conditions such as amount of infection of the leaves, time spent upon the infected leaves, activity of the insect upon the leaf, etc. As a rule, except as noted above, the number was small, running from a single spore upon a foot or antenna to a few clusters caught in hairs or bristles, or stuck upon the feet.

The observations of sporidia upon insects were few. They were observed, however, on a few ants upon infected bushes and on the ground under the bushes.

Inasmuch as quite a large numbers of insects visit Ribes bushes, it is easily comprehended that there is some possibility of their spreading the blister rust by carrying away the urediniospores that are present in some abundance, especially in large infestations. To determine the reality of such a possibility, a series of inoculations was tried.

INOCULATIONS BY MEANS OF INSECT CARRIERS

Three methods of "loading" the insects with urediniospores were employed. In one the insects were allowed to run over diseased leaves placed bottom side up in a petri dish for a few hours or over night. In another, the insects were placed for a like period in petri dishes the lower half of which had been sprinkled with urediniospores shaken from diseased leaves. In the third method insects were taken directly from diseased leaves, some being examined to determine the presence of spores and the remainder used for the inoculation. The insects bearing the spores were transferred by means of sterile forceps to the lower side of leaves of *Ribes prostratum* which had previously been moistened, and the

plant and insects then enclosed in a moist chamber with as much dispatch as possible. The moist chambers used were 2-quart glass jars with tin tops, through each of which a hole had been cut to allow for the entrance of the stem of the inoculated plant. This top, after the stem was inserted, was then clamped upon the jar with a spring clasp. A number of shoots of *Ribes prostratum* at least equal to the number of the inoculated shoots, and usually greater, were treated in a similar manner except for the introduction of the insect, as controls.

Some difficulties were experienced in handling the active insects, as might be expected. The results were marred in no case, but the very difficulties will emphasize the ease with which insects can inoculate Ribes. They were placed on the lower side of the leaves to insure their being there for at least one brief moment. Larvae, in order to leave, would have to crawl off and in so doing would leave enough spores to inoculate the leaf. They might, however, return and eat the results of the inoculation. In one or two instances, all but one or two leaves of the inoculated shoot were eaten by the larvae, but infection on the remaining leaves established a positive result. The adult insects invariably hopped, flew, or crawled from the leaves to the walls of the moist chamber almost immediately; in fact, there was always difficulty in getting the moist chamber closed and fastened before the insects had an opportunity to escape. They then crawled over the inside walls of the glass jar a greater part of the time seeking a place to make an escape. Yet, even with such handicaps, the inoculations were uniformly successful. The results are given in table 3. All inoculations were made on *Ribes prostratum*, all resulted positively, and all the checks remained healthy.

The insects used for the inoculations were those most numerous on the Ribes and those which ordinarily carried quantities of the spores. The leaf hoppers would be included in this class, but they were not used because of the difficulty of handling them. But sufficient variety was possible without them—measuring worms, sawfly larvae, a spiny caterpillar, rose beetles, ants and stinkbugs. It will be noted that the manner of getting the inoculum upon the insects did not matter; the results were positive whether measures were taken to insure the presence of large quantities of spores or the insects had them when caught. Insects taken from diseased bushes had a sufficient quantity of viable spores to produce infection.

CONCLUSIONS FROM OBSERVATIONS ON INSECTS AS CARRIERS OF CRONARTIUM RIBICOLA SPORES

It is undoubtedly true that every insect which enters an infected white pine plot is likely to become a carrier of aeciospores or urediniospores. The part played by wandering insects in the spread of the blister rust may be considerable; while the part played by insects which are more or less confined to their pine host is naturally very limited. The results

TABLE 3

Results of inoculations of Ribes prostratum by insects bearing urediniospores of Cronartium ribicola, Lewis, N. Y., in 1918

DATE	INSECT	METHOD OF LOADING INSECT	NUMBER OF CHECK PLANTS (OR JARS)	RESULTS POSITIVE IN
				days
June 18	Measuring worms Geometridae spp. (Lepidoptera), 1 jar	Insect over night on diseased leaves	1	13
July 13	Rose beetles,			
	1 jar larvae	Insect over night on diseased leaves	2	16
	1 jar adults	Insect over night on diseased leaves	2	16
July 15	Measuring worms, 2 jars	Natural—from diseased plant	2	14
	Larvae of saw-fly, 1 jar	Natural—from diseased plant	2	14
	Large spiny caterpillar—(lost, not identified)	Natural—from diseased plant	2	14
July 16	Large ants, 1 jar	On diseased leaves over night	4	13
July 26	Stink bugs, 1 jar	Allowed to run over spores in Petri dish	3	14
	Stink bugs, 1 jar	Natural—from diseased plant	3	14

presented herewith simply strengthen the hypothesis that practically all insects may become at times the carriers of the spores of a given disease. The conditions under which they become effective carriers of the disease may vary according to the virility of the disease, weather conditions, and other factors which we cannot definitely understand. The conditions governing the spread of the blister rust by aeciospores or teliospores require that the spores pass readily between the alternate hosts, pine and currant or gooseberry. It is doubtful whether the common pine living insects, even though they become completely encrusted with aeciospores, are very important agents in the spread of these spores to Ribes. The

gypsy moth larvae, however, might easily be blown for long distances and would be as likely to feed on Ribes as upon any other plant on which they happen to come to rest. Special attention may be directed to the results indicated in the case of the insect no. 40 in table 1, *Serica sericea*. On the body of this insect it was estimated that there were thirty aeciospores. The estimate was arrived at after repeated careful countings. The insect was collected while it was eating the leaves of a red currant bush, at a distance of 1 mile from pines infected with *Cronartium ribicola*. No urediniospores were found on its body. The insect apparently had in some way come in contact with a sufficient number of aeciospores to retain at least thirty of them and had then, by chance, flown to the currant bush. In this particular case, therefore, there is definite evidence that this very cosmopolitan insect was acting, accidentally perhaps but nevertheless definitely, as an agent for transporting the rust spores from the pine to the necessary alternate host, Ribes.

The possibility of insects spreading the blister rust urediniospores on the currants and gooseberries needs no further elaboration. In all probability only a small fraction of the number of species of insects to visit Ribes during a summer are represented in table 2, and many more of the species would probably be found to bear urediniospores if more attention could have been paid to the collection of insects in the vicinity of infected bushes. The number of individuals observed bearing spores upon their bodies and appendages is certainly only an indication and has no real quantitative value, from the point of view of the amount of blister rust dissemination by insects. According to the entomologists, many of the insects, notably some of the larval and adult *Lepidoptera* enumerated in table 2 do not "belong" on Ribes but certain of them were found with great frequency.

The evidence of insects carrying sporidia is meagre. Ants from infected bushes and also from the litter of fallen infected leaves upon the ground under the bushes were observed to carry a few sporidia. Ants were observed to crawl upon pine trees near infected Ribes bushes to tend the apids and feed, and it is entirely possible that they may thus serve to spread the rust directly to the pines. One larva found occasionally on Ribes is known to feed upon *Pinus strobus*. This is *Neodiprion pinetum* Nort., the white pine sawfly. According to Mr. Rohwer of the Bureau of Entomology, however, the probability is that these larvae taken on Ribes were on their way to pupate on the ground and as their period of pupation is ten to fourteen months, there is little or no possibility that they could carry spores from one alternate host to the other. The only possibility lies in the chance that larvae might return from the Ribes to the pines again.

SUMMARY

A number of species of insects, chiefly beetles, were found in June, 1917, on or near blister rust lesions on white pine, bearing aeciospores in varying quantities. One beetle (*Serica sericea*) was collected feeding upon a red currant bush and bore aeciospores on its body. Slugs, spiders, and many species of insects are habitual frequenters of or casual visitors to Ribes bushes, wild or cultivated.

Many species of insects were found in 1918 to bear urediniospores from infected leaves, some in large quantities. Sporidia were found in a few cases on ants. One insect (*Neodiprion pinetum*) collected upon Ribes is known to feed upon *Pinus strobus*.

Inoculations prove that insects may spread the urediniospore stage from bush to bush.

Hence, while the spread of *Cronartium ribicola* by the agency of insects from pine to Ribes or vice versa may be infrequent and accidental, the spread of the uredinial stage upon Ribes probably occurs with some regularity.

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THE SURFACE ROT OF SWEET POTATOES

L. L. Harter and J. L. Weimer

With Plate XXXV

INTRODUCTION

Ever since the investigations of the diseases of sweet potatoes were begun in 1911, a rather striking form of decay has been under observation and study. Because of its restriction to isolated spots on the surface of the potato, the common name "surface rot" is proposed. The farmers, although recognizing its importance as a storage trouble, have generally considered it as originating in wounds made in the handling of the crop, and therefore largely unavoidable.

To control the several diseases of sweet potatoes, it has been recommended that only healthy and unwounded potatoes be used for seed. These recommendations resulted in many inquiries as to the safety of using potatoes with surface rot spots for seed. In fact, the disease was so prevalent in some storage houses that seed potatoes entirely free of it could not be obtained. Surface rot and stem rot were thought at one time to be caused by the same fungus and if such was the case the question of seed selection would be of great importance.

In view of these facts it was necessary to determine: (1) The cause. (2) The connection, if any exists, between the organism and any disease of the crop in the field. (3) Whether the disease is transmitted to the succeeding crop. (4) The mode of infection. (5) The relation of weather conditions at digging time and the conditions of storage, to the severity of the disease.

DISTRIBUTION AND ECONOMIC IMPORTANCE OF SURFACE ROT

Sweet potatoes affected with surface rot have been collected or received from practically every state where they are grown.

The loss from surface rot varies greatly in different years. During the winter of 1917–1918, it was large throughout the country and especially in the northern part of the sweet potato belt. In some storage houses, where conditions were favorable for the disease, nearly every potato had from one to several spots and the actual loss ran as high as 25 per cent.

The disease is apparently more severe on some varieties than others. However, positive data on this point are lacking, since but few varieties are grown in any one locality, and therefore a comparison of the influence of the conditions of harvesting and storage cannot readily be made. The Big Stem Jersey and Little Stem Jersey varieties are both very susceptible, the former more so than the latter. During past seasons the losses of the Big Stems from surface rot have been so large that farmers are refusing to grow them. Some of the varieties of the South show less surface rot than the Jersey types of the North, which may be due either to natural resistance or to more favorable conditions for harvesting and storage.

Although the spots made by the surface rot organism are relatively shallow, the unsightly appearance caused by them reduces considerably the market value of the potatoes and in extreme cases renders them unsalable. Owing to the large demand for sweet potatoes during the last two or three years, farmers have been able to dispose of their crop to good advantage even though the potatoes were badly marked by surface rot. In previous years, however, such potatoes either could not be marketed, or only at a very much reduced price.

DESCRIPTION

Surface rot is characterized by the nearly circular, brownish, somewhat sunken spots. These spots, usually several in number, vary in size according to age, attaining a maximum diameter of about three-fourths of an inch (plate XXXV, fig. D). The rot is shallow, seldom penetrating below the fibro-vascular ring (fig. E). There are three well marked stages in the development of the disease, the first of which consists in the formation of spots of varying sizes on the potato with no other apparent injury (figs. A and B). In the second there is some shrinkage of the potato, especially at the margin of spots and between them if they are close together (fig. C). The final stage is characterized by a drying up of the potato, rendering it useless for food (fig. D). The third stage is naturally most pronounced at the latter part of the storage period.

Surface rot has characteristics in common with black rot, caused by *Sphaeronema fimbriatum*, and with certain types of wounds, but it is sufficiently distinct to be distinguished readily from both. In general the spots are smaller than those caused by the black rot fungus and usually do not exceed three-fourths of an inch in diameter. Black rot lesions, on the other hand, may be two inches or more in diameter or may even involve the entire potato. The surface rot spots are grayish brown to brown in color, while those of black rot are darker. After once becoming familiar with surface rot it is not likely to be confused with spots caused

by bruises, which are irregular in shape and size while the surface rot spots are usually circular or nearly so. They differ also in the fungi that can be isolated from them. Many different organisms were isolated from bruised spots, no one of which predominated, while one species of Fusarium prevails in the surface rot spots.

The evidence at hand indicates that infection takes place at digging time or a little before it, or early in the storage period. Potatoes dug during or following a wet period show small inconspicuous rotted areas at the base of the small rootlets. Plate XXXV, figure A, shows the small dead rootlets at the center of the spots where infection evidently took place. The spots enlarge in storage from these centers. It is also likely that some infections take place in the storage house. Many farmers have noticed that surface rot is worse when the harvesting is done during rainy weather or while the soil is still wet, and similar observations have been made by the writers.

Surface rot is not conspicuous until six weeks or two months after the potatoes have been in storage. It develops slowly and in New Jersey seldom becomes very noticeable until the potatoes have been in storage for about two months.

THE CAUSE OF SURFACE ROT

Hundreds of isolations were made from diseased sweet potatoes from all parts of the country and one fungus, a species of Fusarium, always predominated. Occasionally, as might be expected, some other fungus was isolated. So far as the writers were able to determine by a comparative study, the causal organism is identical morphologically with cultures of *F. oxysporum* identified by Wollenweber and by Carpenter. The only other species with which it might be confused is *Fusarium hyperoxysporum*, one of the species causing stem rot. *F. hyperoxysporum* forms abundant pionottes in culture on stems of *Melilotus alba*, while the organism producing surface rot forms reduced pionottes or none at all. It differs from *F. hyperoxysporum*, biologically in that the latter causes the stem rot disease, while many inoculations on stems of living plants with *F. oxysporum* from surface rot lesions have never resulted in infection. Furthermore many surface rot potatoes have been bedded and in no case has stem rot developed in the sprouts or to any greater extent in the field later in the season than in plants from potatoes free from surface rot.

There seems therefore no ground for the claim that stem rot is worse where surface rot is prevalent. The work was conducted especially with this idea in mind, and although numerous experiments were made, no evidence of a connection between stem rot and surface rot was obtained,

INOCULATION EXPERIMENTS

From the many organisms isolated from surface rot spots a number were selected to be used for inoculation purposes. Healthy potatoes were selected, cleaned, and inoculated by inserting spores and hyphae beneath the epidermis. Usually several inoculations were made on the same potato and each wound was encircled with a blue pencil. Some of these potatoes were wrapped with filter paper and then in oiled paper to retain the moisture. Those that were not wrapped were laid in moist chambers with wet filter paper in the bottom and under the lid. A considerable amount of moisture is required to bring about infection under the conditions of the experiments, as shown by the fact that no surface rot spots developed on potatoes not wrapped. On the other hand, where the potatoes were wrapped, surface rot developed in the course of about six weeks. Better results were obtained at a temperature of about 10 to 11°C., than at higher temperatures. Lower temperatures were not available and were consequently not tried. These experiments were repeated several times with the same species of *Fusarium* (*F. oxysporum*) with similar results. *F. hyperoxysporum* was also tried in the same way but little or no infection resulted.

The same organisms used in the above experiments and several others isolated from surface rot spots were used to inoculate young sweet potato plants in the greenhouse. Several weeks after these inoculations were made, a few of the plants showed some evidence of infection. The symptoms, however, were not typical of stem rot in the field. The fibrovascular bundles were blackened for an inch or two above and below the point of inoculation. Isolations were made from such plants and inoculations made from these cultures into young plants growing in the field. Under field conditions none of the plants inoculated with the above strains or with other strains isolated from surface rot spots showed any evidence of the disease. On the other hand a large percentage of the plants inoculated with *F. hyperoxysporum* were infected and finally killed. The following year, 1918, similar field inoculations were made with a number of strains from surface rot spots and in no case did infection result.

Further evidence that there is no connection between stem rot and surface rot was obtained in the following manner. In southern New Jersey, surface rot was very prevalent during the winter of 1916–1917. From a storage house where the disease was severe a quantity of surface rot potatoes were selected for seed and divided into two lots. One lot was disinfected in mercuric chloride 1-1000 for ten minutes. These two lots, together with potatoes free from surface rot as checks, also disinfected, were bedded in the usual way. The sprouts from these

three lots were planted along side of each other and notes were taken from time to time on the development of stem rot. At the end of the season there was very little stem rot in any of the lots and no more on the plants from the surface rot potatoes than from the checks. This experiment was repeated and similar ones conducted in other parts of the state with like results. The disease evidently has no connection with stem rot, neither is it transmitted to the succeeding crop by the use of surface rot potatoes for seed.

CONTROL

The apparent dependence of surface rot upon weather conditions at the time of digging and the storage conditions immediately thereafter makes its control especially difficult. It has been pointed out that surface rot is worst when potatoes are dug just following a rain or during wet weather. Potatoes put into the storage house several days before the curing process is begun are more subject to surface rot. Since sweet potatoes intended for storage are not usually dug until late in the fall, it is not always possible to wait for the most favorable weather conditions. It is therefore, sometimes necessary to go on with the harvesting in spite of the wet condition of the soil and even during damp weather in order to finish harvesting before freezing weather. When possible the potatoes should be harvested during dry weather and allowed to dry in the sun for a few hours before going into the storage house. Furthermore, the storage house should be dry and warm when the potatoes are put in so that curing will begin promptly. Especially is this desirable if the potatoes are dug from a wet soil during cloudy weather when there would be little opportunity for drying in the field.

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PLATE XXXV. THE DIFFERENT STAGES IN THE DEVELOPMENT OF SURFACE ROT

FIG. A. An early stage with typical circular, somewhat shrunken lesions, with a small rootlet usually evident in the center.

FIG. B. A slightly more advanced stage as shown by the fact that most of the rootlets have dropped off leaving a small cavity in the center of each spot. The potato has just begun to shrivel, due to the loss of water.

FIG. C. A somewhat later stage showing a shrinkage of the potato and enlargement of the spots.

FIG. D. A sweet potato reduced by surface rot to a hard mummy.

FIG. E. A cross section through a sweet potato affected by surface rot. The blackened areas denote the depth to which the rot has penetrated.

HARTER AND WEIMER: SWEET POTATO SURFACE ROT

BRIEFER ARTICLES

WIND, AND THE DISTRIBUTION OF PATHOGENIC SOIL ORGANISMS

H. G. MacMillan

With Plate XXXVI

The question has often been asked how soils which never were under cultivation became infected with fungous organisms causing plant disease. Pratt[1] (p. 97) has stated that fungous forms were found to be abundant in desert soils causing potato diseases. He referred especially to Fusaria and Rhizoctonia. No explanations have ever been offered for these facts, and, except for one or two notes, no serious consideration seems to have been given the subject. Harter[2] (p. 301) in speaking of the dissemination of the spores of *Fusarium batatatis*, which live over winter in the soil, says they may be carried from place to place by strong winds which raise clouds of dust during certain seasons of the year. Dissemination of spores directly by the wind from the source has been more often noted. Anderson[3] has shown that the spores of *Diaporthe parasitica* are carried many feet; Jones[4] (p. 20) finds evidence that the spores of *Gymnosporangium juniperi-virginianae* are carried half a mile or more. Heald[5] (p. 14) shows that the spores of *Tilletia tritici* are carried 2 and 3 miles and probably much farther. Soil fungi would be more difficult to trace.

The plains on the eastern slope of the Rocky Mountains have a uniform and gradual rise to the west. Over areas of several thousands of square miles there are no conspicuous depressions or elevations, except for an occasional butte. It is common at different times of the year, especially in the early spring, to have high winds of considerable intensity and duration. Some small areas seem to be more subject to winds

[1] Pratt, O. A. Soil fungi in relation to diseases of the Irish potato in southern Idaho. In Jour. Agr. Res. **13**: no. 2, p. 73–99, pl. A and B (col.). Literature cited, pp. 98–99.

[2] Harter, L. L., and Field, Ethel C. The stem rot of the sweet potato (Ipomoea batatas). In Phytopathology **4**: p. 279–304. 1914.

[3] Anderson, Paul J. Wind dissemination of the chestnut blight organism. In Phytopathology **3**: 68. 1913.

[4] Jones, L. R., and Bartholomew, E. T. Apple rust and its control in Wisconsin Wis. Agr. Exp. Sta. Bul. 257. July, 1915.

[5] Heald, F. D., and George, D. C. The wind dissemination of the spores of bunt or stinking smut of wheat. Wash. Agr. Exp. Sta. Bul. 151. December, 1918.

than others, but very large areas may be subject to them at the same time. North and east winds may be particularly violent. It is not unusual for winds having a velocity of 40 to 50 miles an hour to blow throughout an entire day, and often for more than one day at a time. These winds are very drying, and will move a large quantity of soil. The heavier top soil blown from fields drifts at fences and roads the same as snow drifts from them in winter. Plate XXXVI, figure 1 shows the results of a two days' blow across a wheat field. The road is filled to a depth of a foot or more with fine sandy loam. It carries with it all that the soil contains in the way of soil organisms. Along the fence the deposit in times past has changed the contour so that the fence, having made a ridge, is now placed on top of it. Figure 2 shows a closer view of one of the drifts at the fence, with the striations so characteristic of snow. This phenomenon of drifting sand is common in connection with sand dunes. A general microscopic examination of the soil from these drifts showed the spores and mycelial fragments of unidentified fungi to be present.

At times winds are strong enough, and carry so much soil, that horses plowing have to be taken from the field; small pebbles carried by the wind can be heard to strike buildings; boards and loose little objects fly; the eyes have to be protected.

On April 14, 1919, there occurred a dust storm of long duration and great violence. According to the daily weather map issued at Denver, a cyclonic area of considerable though not violent intensity passed over the western plains States, coming from the northwest, and passing south to about the middle of the country, and then eastward. The daily weather map issued on that date shows a cyclonic area over Kansas. It is, of course, a well-known fact that in the northern hemisphere air currents are levorotatory about a low pressure area. This map is orthodox in indicating westerly winds for eastern Colorado. On the map of April 15 the cyclonic area had centered over Illinois and the situation in Colorado had altered to variable winds. These maps can not go into detail for small areas, and so may be misleading.

As was learned by observation, and afterwards by correspondence with people in many parts of eastern Colorado, a general east wind prevailed all day, except in one or two restricted localities. On April 14 the author was enroute from Greeley, in the northern part of Colorado, to Walsenburg, 225 miles to the south. Dust could be seen being blown during the greater part of the day, but the force of the wind could not be estimated. In the afternoon a peculiar change took place. The wind did not sweep the surface with its customary horizontal directional movement, but turned to a decided upward movement, licking up great quantities of dust and carrying it to the upper air. At a certain high point between Pueblo

and Walsenburg one could see north and south for many miles. A cloud of dust over half a mile high, of very great density, and extending as far as eye could see, swept slowly to the west, much as a bank of fog rolls in from the sea. This same phenomenon occurred north of Denver, over 140 miles away.[6] This dust swept on to the mountains, where a natural barrier was encountered. It is reported[7] that at Pike's Peak and Manitou it "snowed red," indicating that the red dust particles were so thick in the air as to cause a precipitation, which at that altitude turned to snow, and gave decided color to the snowfall. The following day the air was clear.

At that time of the year most cultivated fields are fallow or have been planted only a short time. It is reported[8] at Boulder, and it occurred elsewhere, that the seed of spring wheat was blown from the ground. The quantity of soil matter lifted by the wind and transported to an indefinite distance can not be estimated even vaguely. The storm was known to be general over an area of 52,000 square miles, and probably extended much farther. Storms of this kind seem often to have been noticed by geologists.

It is desired to point out that winds and dust storms of the kind described may very well account for the distribution of soil fungi and bacteria over a large territory. There are other effective agencies, to be sure, such as modern transportation facilities afford, and grazing animals. The illustrations demonstrate that infection from field to field may easily be accomplished by wind. Infection from section to section and from township to township may reasonably follow by the same method. Should the potato wart disease get started in a region of this kind, and though it became recognized and quarantine measures were instituted, might not the wind eventually carry spores to fertile ground? There are no effective measures which can be taken to keep the wind from lifting the soil in a semiarid region. Crops covering the ground are the most effective means. On high-priced irrigated land areas are fallow for a portion of the year. It can not be otherwise.

No good method is available to trace organisms transported in this way over a long distance; they fly too high. These observations are, therefore, only conjectural, but it seems likely, in view of the circumstances set forth, that the wind is an active agent in the distribution and dissemination of organisms present in the soil and pathogenic to our field and truck crops.

Bureau of Plant Industry
Greeley, Colorado

[6] Letter, George R. Smith, County Agent, Brighton, Colo.
[7] Letter, W. H. Lauck, County Agent, Colorado Springs, Colo.
[8] Page 4, Rocky Mountain News, Denver, Colo., Tuesday, April 15, 1919.

FIG. 1

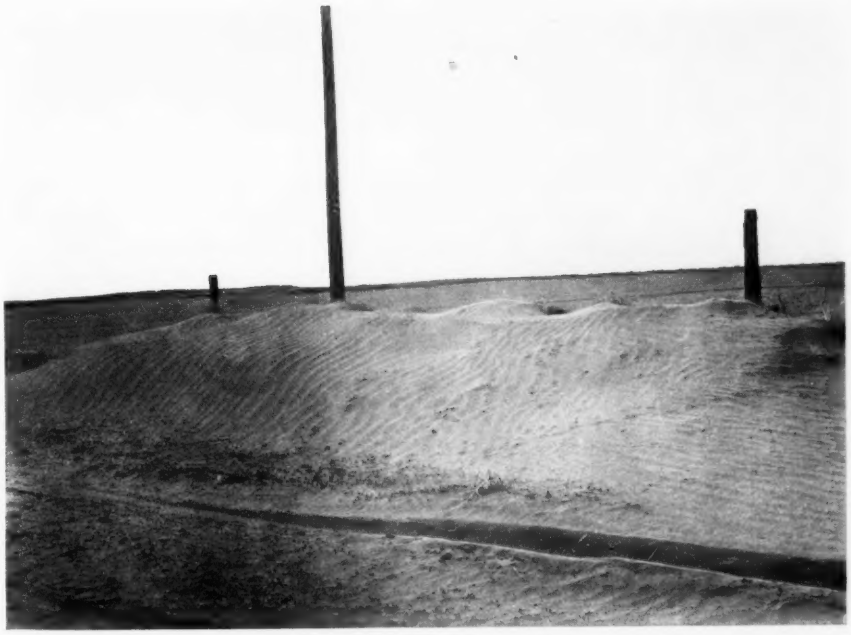


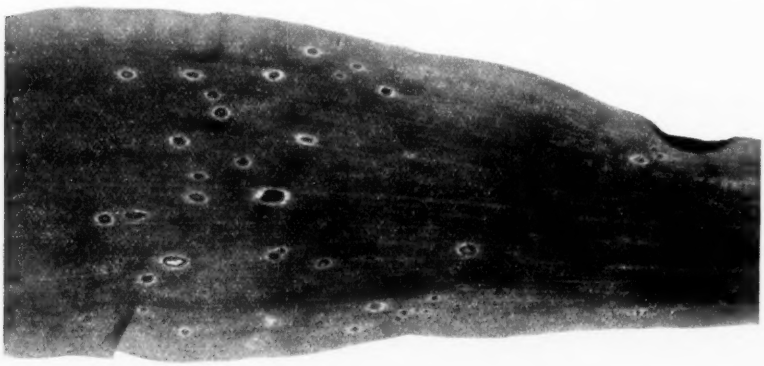
FIG. 2

PHYTOPATHOLOGICAL NOTES

Frost necrosis of tulip leaves. This spring there developed almost simultaneously in several gardens in Madison a peculiar spotting of tulip leaves, and examples of the same have been sent us from other points in the state. In all cases the plants affected were of the Darwin type and were either on low ground or so situated as to be exposed to the frosts which occurred about a week before the spots were first noted. The lesions are worthy of description because of their striking resemblance to a typical bacterial leaf spot. Some are circular in outline, but the greater number are oval and occur on or between the veins of the leaf with their long axes parallel to the veins. They vary in size from 1 to 3 by 1.5 to 4.5 mm. with an occasional spot measuring 5 by 8 mm. or more. In addition are numerous irregular larger dead areas, perhaps in some cases due to the merging of smaller spots. The smallest spots have brown centers surrounded by a pale yellowish-green water-soaked area, while the larger ones have pale yellow to brown dried-out centers surrounded by a brown area and the same definite water-soaked margin.

In these characters, as has been previously noted, there is in the smaller spots a striking resemblance to a bacterial lesion. On the other hand, there is no evidence of a cloudy exudate upon these spots when moist, or of any incrusting residue where the spots have dried out. Instead, as the dead tissues are allowed to dry, the smaller definite spots become white and blistered in a manner characteristic of frost injury. No evidence of bacterial invasion could be detected by microscopic examination of sections through the water soaked areas, and plating out of interior tissues gave negative results. We have therefore felt justified in our conclusion that the spotting is non-parasitic and doubtless due to frost injury. As already noted it has in our observation been restricted to tulips of one type, the Darwin, even where these occurred in mixed plantation with others, and it is our interpretation that this is more susceptible to frost necrosis than other tulip strains. As bearing on this it is to be noted that the Darwin represents a distinct type, and that such varietal differences in susceptibility to frost necrosis are common. For example, the senior author had opportunity to observe in 1910 that the white lilac is distinctly more susceptible under the same exposure than is the common purple variety of the same species (*Syringa*

vulgaris). We have felt the more confidence in our conclusion as to the origin of this injury because previous observations have shown that similar spotting or other types of local injury are rather common on other herbaceous plants which have been exposed to light frosts. Frost blistering of leaves has been frequently recorded.[1] Harvey reports[2] frost spots on the leaves of cabbage and tomato. We have repeatedly observed the development of definite small spots upon the leaves of red clover, alfalfa,



FROST NECROSIS OF TULIP LEAF. × ⅔

Note water soaked areas surrounding dead spots, also the fact that spotting is near middle of leaf.

and sweet clover, both in spring and autumn, following light frost. Indeed, such spotting was prevalent this spring simultaneously with that on tulips. A somewhat less definite spotting also occurs on leaves of cereal grains when subjected to mild frost injuries during the seedling stage.

In all these cases the lesions of frost necrosis were so strikingly suggestive of bacterial leaf spotting that we believe it important to bear in mind the possibility of confusion between such lesions and the bacterial leaf spots on the various hosts.

L. R. JONES AND M. MILLER

Kerosene injury to shade trees. About the middle of June this Department received an inquiry concerning the dying of shade trees. The man stated that between 1914 and 1918 a number of fine shade trees, especially maple, on his grounds, had died and that several more appeared to be

[1] Stewart, F. C. Two unusual troubles of apple foliage. N. Y. Agr. Exp. Sta. Bul. 220. 1902.

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[2] Harvey, R. B. Hardening process in plants and developments from frost injury. Jour. Agr. Res. **15**: 85, Oct. 14, 1918.

in a very unthrifty condition. The information sent was inadequate to enable us to diagnose the cause, so a trip was made for the purpose of inspecting the trees.

Upon examination it was found that the bark, cambium, and even the sapwood of the trees had been killed in a zone 3 inches wide at a height of about 4 feet from the ground. In addition to this zone there were large areas extending downward from it in which the outer tissues had been killed and the bark and bast could be easily removed in large sections, exposing dead and discolored sapwood. The trees still living showed similar injury except that there could be found small strips of living tissue, from 1 inch to 3 inches wide where the cambium and other tissues had not been destroyed. These strips were always situated in depression in the trunk. Calluses were being formed around the dead areas so that the limits of injury were very distinct.

In discussing the situation it was learned that three years ago there had been a plague of tussock moth in the vicinity. In order to prevent the larvae from crawling up the tree trunks, bands of cotton wool had been placed around the trunks at the zone of killing. These bands had been saturated with kerosene a number of times, the excess material being allowed to run down the trunks. From the form and position of the dead areas it was very evident that the kerosene had been the destructive agent.

R. E. STONE

Personals. Mr. W. A. McCubbin, formerly in charge of the Dominion Laboratory of Plant Pathology at St. Catherines, Ontario, has become deputy director of plant industry for the Pennsylvania Department of Agriculture at Harrisburg, Pa. He is located temporarily at Freeland, Pa., where he is assisting in the administration of quarantine regulations for restricting the spread of the potato wart disease.

Mr. A. H. Gilbert, recently extension pathologist for the Bureau of Plant Industry in Vermont, has entered the joint employ of the Vermont State Department of Agriculture and the Agricultural Experiment Station, with headquarters at Burlington.

Mr. W. S. Fields, formerly extension pathologist for the Bureau of Plant Industry in Mississippi, has accepted a position as pathological inspector for the Federal Horticultural Board, with headquarters at Washington, D. C.

Mr. M. R. Ensign has resigned his position in the Bureau of Plant Industry as extension pathologist in Arkansas, to take up work as a

teacher of agriculture in the high school at Lamar, Arkansas. He will also be employed by the Fort Smith Commission Company to look after their plantings of Irish potatoes, sweet potatoes, and other truck crops in the vicinity of Lamar.

Mr. A. C. Foster, formerly an assistant in plant pathology at the North Carolina Agricultural College, has been released from military service and has taken up investigations of cucumber diseases at the Wisconsin Agricultural Experiment Station, Madison, Wisconsin.

Dr. C. H. Kauffman, formerly pathological inspector for the Federal Horticultural Board, has resigned this position and returned to the University of Michigan as a member of the teaching staff in the Department of Botany.

Mr. G. F. Gravatt has recently been discharged from the Navy and has returned to his position as assistant pathologist in the Bureau of Plant Industry. He will be engaged in work on the white pine blister rust and the chestnut bark disease.

LITERATURE ON PLANT DISEASES[1]

COMPILED BY ALICE C. ATWOOD, AND FLORENCE P. SMITH, BIBLIOGRAPHICAL ASSISTANTS, BUREAU OF PLANT INDUSTRY

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All authors are urged to cooperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints or correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. of Agric., Washington, D. C.

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